another star, suggesting that low-density regions of star formation such as the Taurus Molecular Cloud are the most promising nurseries for planets that eventually develop Earth-like environments. One interesting auxiliary result was the calculation of the odds of Earth being ejected or captured from the solar system by another star prior to the Sun's red giant phase: a scant one part in one hundred thousand!

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Stability of the Upsilon Andromedae Planetary System

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This project studies the dynamical properties of planetary systems that are consistent with the observational data on the three-planet system orbiting the nearby main sequence star Upsilon Andromedae. Some configurations consistent with the data originally announced by the discovery team are found to be stable for at least one billion years, whereas in other configurations planets can be ejected into interstellar space in less than 100,000 years. The typical path to instability involves the outer planet exciting the eccentricity of the orbit of the middle planet to such high values that it ventures close to the inner planet. In some stable systems a secular resonance between the outer two planets prevents close approaches between them by aligning their longitudes of periastron (that is, the orientations of their elliptical orbits). In relatively stable systems, test particles (which can be thought of as representing asteroids or Earth-like planets that are too small to have been detected to date) can survive for long periods of time between the inner and middle planets, as well as exterior to the outer planet. No stable orbits between the middle and outer planets were found.

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Hydrodynamic Simulations of Asteroid Impacts on Venus

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Impact cratering is strongly affected by the presence of an atmosphere. Our solar system offers four relevant targets: Venus, Titan, Earth, and Mars. Our greatest concern is with the Earth, but Venus is the best subject to study, because its atmosphere is about 100 times thicker than the Earth's, and the surface of Venus is randomly peppered with a thousand craters, most of which are apparently little altered since their creation. Thus Venus provides the ideal testbed for theories of atmospheric permeability to stray cosmic bodies—there is both strong atmospheric interaction and enough craters to provide ground truth to calibrate results.

In this study, numerous two-dimensional (2-D) high-resolution hydrodynamical simulations of asteroids striking the atmosphere of Venus were performed. The computations used ZEUS, a grid-based Eulerian hydro-code designed to model the behavior of gases in astrophysical situations. The numerical experiments address a wide range of impact parameters (velocity, size, and incidence angle), but the focus is on 1-, 2-, and 3-kilometer-diameter asteroids, because asteroids of these sizes are responsible for most of the impact craters on Venus. Asteroids in this size range disintegrate, ablate, and decelerate in the atmosphere, yet retain enough impetus to make large craters when they strike the ground. Smaller impactors usually explode in the atmosphere without cratering the surface.

In the simulations, the impactor is broken up by aerodynamic forces generated by the rapid deceleration of the bolide and the shearing flow that develops around it. This results in a complicated and turbulent flow at high Mach number, featuring a broad range of exponentially growing unstable waves. The simulations are sensitive to small differences (both physical and computational) in the initial conditions of the computation. It is found that the shape, resolution, velocity, or other details of the impact can strongly influence which wavelengths grow first, and how quickly. The evolution of each impact is unique, highly chaotic, and sensitively dependent on details of the initial conditions. Atmospheric permeability